THE SPREAD OF SEVERAL INTRODUCED OR RECENTLY INVADING AQUATICS IN WESTERN MASSACHUSETTS

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In the course of a larger study of the vegetation of marshes of the Connecticut River watershed in western Massachusetts, changes in the distributional status of several introduced or invading aquatic vascular plant species have been observed. Each of these species was first collected in the area within the present century and has recently increased in sites affected by eutrophication or other habitat disruption; none is yet so widespread that it is regularly encountered in freshwater systems.

The spread of water clover, *Marsilea quadrifolia* L. from Paradise Pond on the Smith College campus in Northampton downstream two miles in disturbed sites along the Mill River during the period 1945-65 has been documented previously (Burk, 1966). Prior to 1969, *M. quadrifolia* failed to establish itself in the Arcadia Wildlife Sanctuary marsh at the mouth of the river, although at least one small colony persisted there for portions of a single season. During summer, 1969, at a time when the Arcadia marsh was severely disturbed by upstream industrial pollution, an oil spill, a dredging operation, and seepage from a municipal dump, *M. quadrifolia* became established over several hundred square feet of exposed substratum near the outlet of the Mill River into the oxbow of the Connecticut. This colony expanded and by early fall of 1970, *M. quadrifolia* was generally distributed and abundant in the marsh (Robinton and Burk, 1971) where it has competed successfully with native vegetation to the present despite a general improvement of water quality within the stream. As of September, 1974, *M. quadrifolia* had not spread into the oxbow of the Connecticut. Colonies of *M. quadrifolia* have maintained themselves along the river between Ar-

cadia marsh and Paradise Pond but have not extended farther upstream than their farthest station, about 1550 feet from the assumed point of release, in 1965.

Wolffia columbiana Karst. was first collected in Massachusetts in 1933 by Manning (1934) in a small marsh at Mt. Tom Station, Holyoke. Eaton (1939) reported *W. columbiana* as abundant in the Great Meadows at Concord in 1938 in water largely derived from municipal filter beds. A third Massachusetts station was reported in 1951 by Harris and Bean at Methuen, Essex Co., while Eaton in 1952, 1957, and 1958 described its increased abundance correlated with increased pollution by alkaline sewage. Livingstone (1967) cites *W. columbiana* as rare in an area encompassing Franklin, Hampshire, and Hampden counties in western Massachusetts except at Leverett Pond, Hampshire Co., where a specimen (MASS 26585) documents its presence as early as 1953. Recently *W. columbiana* has become very abundant at a number of Hampshire County sites including Lake Warner in North Hadley, Aldrich Lake and Forge Pond, Granby, and South Pond in Hatfield. We have observed the Lake Warner site regularly since 1971; *W. columbiana* has persisted on the surface throughout the entire year, reaching densities, in mixed colonies with *Lemna minor* and *Spirodela polyrhiza*, sufficient to cover much of the zone of open water. Lake Warner, Aldrich Lake, and Forge Pond all receive sewage effluents and have been shown to be highly eutrophic compared with other western Massachusetts lakes (Snow and DiGiano, 1973); the increase in *W. columbiana* within this portion of its range thus seems almost certainly correlated with increased enrichment.

The water chestnut, *Trapa natans* L., became well established in eastern Massachusetts during the latter portion of the 19th century, reaching nuisance proportions by 1899 (Cook, 1899) and undergoing a striking increase along the Sudbury River in the 1940's (Eaton, 1947). This later increase was apparently associated with increased levels of soluble nitrates in the stream. The Mount Holyoke College

herbarium contains a fruiting specimen of *T. natans* (*A. M. Starr*, September, 1920) from Upper Lake on the Mount Holyoke Campus in South Hadley and Livingstone (1967) describes *T. natans* as rarely established in ponds within the region. At present, *T. natans* is abundant on Upper and Lower Ponds where herbicides have been used on occasion to control it. Both Upper and Lower Ponds are impoundments of Stony Brook; a search downstream in August, 1974, yielded a well established colony of *T. natans* covering several hundred square feet of water surface behind a dam at an abandoned paper mill near the intersection of Stony Brook with Route 116.

R. B. Livingstone (personal communication) has described a bizarre situation in which *Trapa natans* from the South Hadley population, and *Marsilea quadrifolia* and *Azolla caroliniana* Willd. from the Botanical Gardens of Smith College were deliberately introduced into a pond on the campus of the University of Massachusetts in Amherst in the early 1950's. All three species multiplied at such a rate that the pond was drained in an attempt to eliminate them. *Trapa natans* and *Azolla caroliniana* disappeared after a few years; *Marsilea quadrifolia* remained at pest densities through the middle 1960's but has since declined concomitant with increased turbidity within the pond caused by adjacent construction work. *Azolla caroliniana* has been introduced into various ponds in the Northampton area, both deliberately or through accident, yearly at least since 1966. It frequently multiplies to the extent of covering the entire water surface within a period of a few months but has not as yet survived the winter.

Cabomba caroliniana Gray was first reported from Massachusetts by Manning (1937) who found the species very abundant in South Pond, an ancient oxbow of the Connecticut River in Hatfield, Hampshire Co. Manning quoted a local florist as having observed *C. caroliniana* in abundance there for at least ten years; Manning's first collection of *C. caroliniana* at the site was made in 1930. Gates (1958) documents the extent of its occurrence in the state through

the 1950's; the South Pond station was the only collection west of Worcester Co. Hodgdon (1959) noted its spread at pest densities in Rockingham Co., New Hampshire.

The South Pond population has maintained itself to the present, *Cabomba caroliniana* comprising a major proportion of the submergent vegetation in the pond but not spreading downstream in Cowbridge Brook, which drains the oxbow into the Connecticut. Flowering and fruiting do not occur regularly on an annual basis in South Pond. In September, 1972, numerous specimens of *C. caroliniana* were observed there in flower or fruit, while during an extensive 1974 study of the vegetation of the pond, no flowering whatever was observed. In Lake Rohunta in Worcester and Franklin Counties a population which has persisted at least since 1963, as evidenced by specimens in the herbarium of the University of Massachusetts (MASS 47419, 47421), was observed flowering in October, 1974. *Cabomba caroliniana* is the dominant submerged aquatic throughout much of Lake Rohunta; is now occurs also in nearby South Athol Pond and has spread from Lake Rohunta from drainage into a tributary of the Millers River. We have also collected *C. caroliniana* with *Trapa natans* at its lowermost site on Stony Brook in South Hadley. *Cabomba caroliniana*, the origin of which is presumably more southerly areas, remains in actively growing condition later than other submerged aquatics, including *Ceratophyllum demersum* L. and various species of *Potamogeton*. Indeed, we observed and later collected bright green shoots of *C. caroliniana* in water under a layer of ice in Lake Rohunta in late January, 1975.

Miscanthus sacchariflorus (Maxim.) Hackel has been reported from two New England stations, one of which is in eastern Massachusetts (Seymour, 1969). We have found this grass, a native of China and Japan, well established around the edges of a small pond bordering the eastern side of Route 116 in South Hadley, Hampshire County.

Specimens of all species mentioned in this paper have been deposited in the Smith College herbarium. Nomen-

clature follows Fernald (1950) except in the instance of *Miscanthus sacchariflorus*, which he does not include.

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